

## APPARATUS AND METHODS FOR INITIALIZING INTEGRATED CIRCUIT ADDRESSES

### BACKGROUND OF THE INVENTION

#### 5 1. Technical Field

The invention pertains to communication among a controller and integrated circuits, and in particular embodiments, to initializing integrated circuit addresses.

#### 2. Related Art

10 Microelectronic devices may include multiple integrated circuits (ICs) that operate in conjunction with a controller. In such devices, it is necessary to provide a manner of communicating data between the controller and the ICs. In the interests of miniaturization, it is typically undesirable to use separate dedicated communication lines between each IC and the controller. As a result, a shared bus approach is preferred for most applications.

15 An example of a conventional shared bus system is illustrated in Figure 1. The system includes a controller 10 and several integrated circuits (ICs) 12, 14, 16. The integrated circuits may be any of a variety of well known types of ICs including application specific integrated circuits (ASICs), digital signal processors (DSPs),  
20 mixed signal processors, and microprocessors. Although three ICs are shown in Figure 1, the number will vary depending on the application.

The controller communicates data to and from the ICs through a shared bus 18. In order to distinguish communications on the shared bus, each IC is assigned a unique address. The address of each IC is initialized during system initialization.  
25 In the system shown in Figure 1, a four bit address is communicated to each IC in the form of single bits provided on individual dedicated address lines 20. However, as seen in Figure 1, the system requires separate address lines for each IC, and each address line occupies a separate pin of the controller and of an IC. This arrangement is undesirable because pins are scarce in miniaturized circuits, and the

pins used for the address lines in the conventional system are typically not used for any further purpose. Consider that, for example, if it is desired to use sixteen ICs, a total of 64 individual address lines would be required, occupying 64 pins of the controller and four pins of each IC. This eliminates valuable resources at both the controller and the ICs, and may limit the number of ICs that can be used in a given system to a number that is less than would otherwise be desired.

In an alternative to the system of Figure 1, addresses may be preassigned to each IC by tying address pins of each IC to high or low levels. While this eliminates the need to occupy pins on the controller, it still occupies a large number of pins on each IC, and it complicates the manufacturing process by requiring manual address configuration during manufacturing, since the ability to configure IC addresses during operation is eliminated.

#### SUMMARY

Embodiments of the invention provide systems that optimize the number of pins required to assign addresses to ICs in a multiple IC shared bus system. Further embodiments of the invention provide processes within multiple IC shared bus systems that assign addresses to ICs in a manner that minimizes the number of pins required.

In accordance with an embodiment of the invention, a system includes a controller and multiple ICs. The ICs communicate with the controller over a shared bus. The ICs are further joined to an output of the controller in a daisy chain configuration. In accordance with one embodiment of the invention, the controller produces address data that is sent to a first IC through the daisy chain connection. The IC stores the address in its address register and provides incremented address data to the next IC in the daisy chain. In accordance with another embodiment of the invention, the controller produces an enable signal that is sent to a first IC through a daisy chain link. At the same time, address data for the first IC is

provided on the shared bus. In response to the enable signal, the IC stores the address on the shared bus in its address register. The enable signal is thereafter propagated to successive ICs over daisy chain links in conjunction with successive addresses provided on the shared bus.

5 Other systems, methods, features and advantages of the invention will be or will become apparent to one with skill in the art upon examination of the following figures and detailed description. It is intended that all such additional systems, methods, features and advantages be included within this description, be within the scope of the invention, and be protected by the accompanying claims.

#### BRIEF DESCRIPTION OF THE FIGURES

10 The invention can be better understood with reference to the following figures. The components in the figures are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the invention. Moreover, in the figures, like reference numerals designate corresponding parts throughout the different views.

Figure 1 is an illustration of a conventional multiple IC shared bus system;

15 Figure 2 is an illustration of a multiple IC shared bus system in accordance with an embodiment of the invention;

20 Figure 3 is an illustration of an IC in accordance with a first embodiment of the invention;

Figure 4 is an illustration of a process in accordance with the embodiment of Figure 3;

25 Figure 5 is an illustration of an IC and corresponding timing diagram in accordance with a second embodiment of the invention; and

Figure 6 is an illustration of a process in accordance with the embodiment of Figure 5.

## DETAILED DESCRIPTION

A system in accordance with an embodiment of the invention is illustrated in Figure 2. In the system of Figure 2, multiple ICs 22, 24, 26 communicate with a controller 10 through a shared bus 18. The ICs are also joined to an output 28 of the controller in a daisy chain configuration by daisy chain links 30, 32, 34. Each IC includes an input for receiving a signal on a link of the daisy chain and an output for providing a signal on a link of the daisy chain. The daisy chain links are used for address initialization. Thus only one controller pin and two IC pins are used for address initialization.

The ICs of a system in accordance with Figure 2 may be structured in various manners to utilize the daisy chain configuration for address initialization. Figure 3 shows one embodiment of an integrated circuit that may be employed in a system as illustrated in Figure 2. In accordance with this embodiment, the daisy chain link is used for conveying address data 40 to the ICs. Each IC includes an input 42 for receiving address data 40 and an output 44 for providing incremented address data 46. Each IC further includes an address register 48 where received address data is stored, and output generator logic 50 that increments the stored address. In accordance with this embodiment, a storage medium (not shown) in communication with a controller 10 as shown in Figure 2 stores programming instructions for instructing the controller 10 to produce first address data on the controller output 28. The storage medium is preferably, but not limited to, a non-volatile memory device such as a ROM or flash memory.

Figure 4 illustrates an address initialization process performed in a system as illustrated in Figure 2 and using ICs as illustrated in Figure 3. In this process, the controller initially generates first address data on an output line that is connected to the input of a first IC (52). The address data represents the address of the first IC. The address data may take a variety of forms, for example, a series of pulses equal in number to the value of the address, or a serially transmitted multi-bit binary

address word. The address data is received at the input of the IC (54) and is stored in the address register (56). The address data is also provided to the output generator logic, which increments the stored address value (58) and provides the incremented address data to the output (60). The output port drives a link in the daisy chain connecting the first IC to the second IC in the daisy chain. The second IC in turn receives the address data (62), stores that address in its address register (64), further increments the stored address (66), and provides the incremented address at the daisy chain output from which it is conveyed to a next consecutive IC (68). Thus, upon generating an address of an initial IC at the controller, a series of consecutive addresses is automatically propagated down the chain of ICs in a cascading fashion without further intervention from the controller.

The logic within the IC for processing the input address data signal and generating the output data will vary with the type of address data signal employed. For example, if the address data is represented by a series of pulses, a counter may be employed to sum the pulses to provide a binary address for storage in the address register. Further logic circuitry may be employed, for example, to decrement the counter sum by one to enable storage of a zero address in response to receipt of a single pulse as address data. The output generator may then increment the value stored in the register by two and produce a corresponding number of pulses.

Alternatively, if the address data is provided in the form of a binary word, the address register may simply store the received binary word, and the output generator logic may increment the binary word and provide the incremented binary word as output.

Those having ordinary skill in the art of microelectronics are capable of designing a variety of logic circuits that may be employed for the aforementioned purposes.

In further embodiments, an IC as shown in Figure 3 may comprise a processor with associated memory storing programming instructions for performing the functions of the logic circuits previously described with respect to Figure 3. Thus, the IC may be programmed to receive address data at a daisy chain input, store the address data as the address of the IC in an address register, increment the address data, and provide the incremented address data at a daisy chain output.

Figure 5 shows an alternative embodiment of an integrated circuit that may be employed in the system illustrated in Figure 2. In accordance with this embodiment, the shared bus is used for distributing address data to the ICs, and the daisy chain link is used for distributing an enable signal that enables an IC to store an address present on the shared bus. Each IC includes an input 72 for receiving an input enable signal 70 and an output 74 for providing an output enable signal 76. Each IC also includes an address register 78 where address data 80 received on the shared bus through a shared bus input 82 is stored. Each IC further includes enable signal generator logic 84 that generates an enable signal at the output in conjunction with a change in the address data present on the shared bus. Preferred timing of the output enable signal 76 relative to the address data on the shared bus is shown in the timing diagram of Figure 5. In the daisy chain configuration, the output signal shown in the timing diagram will typically constitute the input signal received by a succeeding IC. Thus, in the embodiment of Figure 5, the ICs are successively enabled to store an address at each change of the address data on the shared bus.

Further in accordance with this embodiment, the controller is programmed to produce a series of addresses on the shared bus and to produce an enable signal on an output in conjunction with a first address of the series of addresses. Programming instructions for causing the controller to produce these signals may be stored in a storage medium (not shown) in communication with the controller.

The storage medium is preferably, but not limited to, a non-volatile memory device such as a ROM or flash memory.

Figure 6 illustrates an address initialization process performed in a system as illustrated in Figure 2 and using ICs as illustrated in Figure 5. Initially, the controller generates an enable signal on its daisy chain output (100), and generates a first address on the shared bus (102). Although Figure 6 shows the enable signal being generated prior to the first address signal, the order of these two signals is immaterial so long as they coincide. The enable signal is received by a first IC on its daisy chain input (104), and the address data is received by the first IC on the shared bus (106). Upon coincidence of the enable signal and the address data, the first IC stores the address in its address register (108).

The controller thereafter generates a second address on the shared bus (110), and the first IC generates an enable signal at its daisy chain output in conjunction with the change of address data on the shared bus (112). The enable signal is received by a second IC on its daisy chain input (114), and the address data is received by the second IC on the shared bus (116). Since the enable signal is present, the second IC stores the address in its address register (118). The controller thereafter generates a third address on the shared bus (120), and the second IC generates an enable signal at its daisy chain output in conjunction with the change of address data on the shared bus (122). In this manner, the enable signal is propagated to each successive IC in conjunction with the changes of address on the shared bus, allowing each IC to store a consecutive one of the addresses in its address register.

The enable signal generator logic 84 of the ICs may be implemented in a variety of manners. In one embodiment, the enable signal generator logic 84 may comprise a timer that is initialized upon receipt of the enable signal 70, and that generates an enable signal 76 after a period of time that coincides with the rate at which address data is changed on the shared bus. In a preferred embodiment, the

enable signal generator logic 84 receives the input signal 70 and shared bus signals as inputs, and produces an output enable signal 76 upon detecting the first change in address data after receiving the input enable signal 70. In this manner, enable signals are not propagated until new address data for the next consecutive IC is available on the shared bus. Thus the enable signals are synchronized with the data rate on the shared bus, eliminating timing problems that could occur in a timer based implementation.

Those having ordinary skill in the art of microelectronics are capable of designing a variety of logic circuits that may be employed for the aforementioned purposes.

In further embodiments, an IC as shown in Figure 5 may comprise a processor with associated memory storing programming instructions for performing the functions of the logic circuits previously described with respect to Figure 5. Thus, the IC may be programmed to initialize a timer upon receipt of an enable signal, and generate an enable signal upon expiration of the timer. Alternatively, the IC may be programmed to receive an enable signal at a daisy chain input, store address data present on the shared bus as the address of the IC in response to the enable signal, detect a change in the address data on the shared bus, and generate an enable signal at a daisy chain output.

While various embodiments of the invention have been described, it will be apparent to those of ordinary skill in the art that many more embodiments and implementations are possible that are within the scope of this invention. Accordingly, the invention is not to be restricted except in light of the attached claims and their equivalents.